Description

COMMERCIAL AIRCRAFT ON-BOARD INERTING SYSTEM

BACKGROUND OF INVENTION

[0001] The present invention relates generally to aeronautical vehicle fuel tank inerting systems, and more particularly, to a system for inerting fuel tank(s) of a commercial aircraft.

[0002] Fuel tanks within wings of an aircraft represent vulnerable areas on all aircraft for the potential for flame initiation due to the existence of fuel vapor and oxygen concentration levels therein. Fuel tank inerting systems are currently used to reduce oxygen concentration levels within fuel tanks of some military aircraft in order to significantly reduce the vulnerability of military aircraft to hostile munitions.

[0003] As is known in the art, as oxygen concentration levels within a fuel tank increase, likelihood of flame initiation and propagation and likelihood of a possible explosion also increases. This threat exists since fuel vapors gener-

ally mix with ambient air that has a 21% concentration of oxygen. It has been determined that when oxygen concentration levels are maintained at a level of approximately 12% or less at seal level (14.5% at 40,000 ft), that the threat of flame propagation or of an explosion from occurring can be significantly reduced or eliminated.

[0004] Some vehicles, principally military vehicles, are equipped with fuel tank inerting systems, which supply nitrogen gas to purge fuel tanks and effectively reduce oxygen concentration levels therein. Of available types of fuel tank inerting systems, the most desirable from a weight, capacity, and ground service requirements stand point is an inert gas generation system that utilizes pressurized air supplied by engine bleed from a gas turbine engine or other airborne source of pressurized air. This air is separated into an oxygen rich component, which is exhausted overboard, and an oxygen depleted or inert gas component, which is fed to the fuel tank.

[0005] Unlike military applications, commercial aircraft ignition threat requirements are not as probable, but other requirements, such as reliability, maintenance and cost of internal components and systems can be more stringent. Military inerting systems often utilize complicated and un-

reliable components to provide nitrogen-enriched air to each wing fuel tank, for all perceivable mission conditions. During combat military missions, threats from hostile munitions are highly probable. The military type systems have a poor reliability history, with high maintenance costs and are oversized for the vast majority of typical commercial aircraft operations.

[0006] The primary flammability exposure for commercial aircraft is in the center fuel tanks, particularly if located adjacent to heat sources. Thus, a primary desire exists in commercial aircraft applications to reduce flammability exposure in center fuel tanks, to a level that is similar to that of the wing fuel tanks. Additionally, reducing exposure in wing fuel tanks can also be desirable when aircraft design characteristics result in high flammability exposure or when additional reduction in wing fuel tank flammability exposure is desired.

[0007] Additionally, it is also desirable for the fuel tank to be inert during both ground and flight conditions. The inerting air need be supplied without use of inerting air storage tanks, which can be heavy in weight, as are commonly used in prior art military inerting systems.

[0008] It is therefore desirable to provide an inerting system that

reduces flammability exposure in fuel tanks of a commercial aircraft during both ground and flight conditions, while at the same time minimizing size, weight, maintenance, and cost, as well as maximizing reliability to be effective and feasible for commercial applications.

SUMMARY OF INVENTION

[0009] The present invention provides a system and method for supplying inerting gas to one or more fuel tank circuits having fuel tanks and maintaining the tanks in an inert condition during ground and flight conditions of an aircraft. An inerting system is provided and includes one or more fuel tank circuits, each of which associated with a fuel tank. An air source supplies pressurized air. A heat exchanger cools the pressurized air. One or more air separation modules receive cooled air from the heat exchanger and separate inerting gas from the pressurized air. A controller controls flow of the inerting gas from the air separation modules to the fuel tanks.

[0010] The embodiments of the present invention provide several advantages. One such advantage is the provision of an inerting system that reduces the flammability of high flammability tanks, such as aircraft center tanks where flammability is generally the highest, thus minimizing

system size and weight.

[0011] Another advantage provided by an embodiment of the present invention is the provision of an inerting system that maintains the tanks at appropriate inerting levels during aircraft ground operations, without continuously operating the system.

[0012] Furthermore, another advantage provided by an embodiment of the present invention is the provision of an inerting system that maintains oxygen content levels within fuel tanks of an aircraft to approximately 12% or less. In so doing, the present invention minimizes weight, size, and cost of an inerting system and provides improved reliability and operational performance.

[0013] Yet another advantage provided by an embodiment of the present invention is the provision of producing inerting gas by utilizing bleed air pressure without the additional need for a compressor, thereby further minimizing weight and maximizing the reliability of an inerting system. Note although there is no additional need for a compressor, the stated embodiment may utilize a compressor when desired.

[0014] Moreover, another embodiment of the present invention minimizes the quantity of bleed air used during climb and

cruise by operating in multiple inerting system modes.

[0015] In addition, another embodiment utilizes the inerting gas provided to the tanks to supply an ejector that mixes the tank air/vapor volume, which minimizes oxygen content variation throughout the tanks.

[0016] The present invention itself, together with further objects and attendant advantages, will be best understood by reference to the following detailed description, taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF DRAWINGS

[0017] Figure 1 is a block diagrammatic and schematic view of an on-board inerting system for an aircraft in accordance with an embodiment of the present invention; and

[0018] Figure 2 is a logic flow diagram illustrating a method of supplying inerting gas to multiple fuel tanks of the aircraft in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0019] In each of the following figures, the same reference numerals are used to refer to the same components. While the present invention is described with respect to a system and method for supplying inerting gas to center fuel

tanks during ground and/or flight conditions of an aircraft, the present invention may be adapted for various inerting system applications known in the art.

[0020] In the following description, various operating parameters and components are described for one constructed embodiment. These specific parameters and components are included as examples and are not meant to be limiting.

[0021] Referring now to Figure 1, a block diagrammatic and schematic view of an on-board inerting system 10 for an aircraft 12 in accordance with an embodiment of the present invention is shown. The inerting system 10 includes an on-board inerting control circuit 14, which controls supply of inerting gas to one or multiple fuel tank circuits 15 (only one is shown). The control circuit utilizes engine bleed air 17 from one or more aircraft engines 18 in supplying the inerting gas. The inerting system 10 also includes an air manipulation and separation circuit 19, which supplies inerting gas to the tanks 16.

[0022] It has been determined for commercial applications that maintaining oxygen content at or below 12% within the fuel tanks 16 is sufficient in minimizing potential for flame initiation therein. The system 10 is sized to maintain oxygen content within the fuel tanks 16 at approxi-

mately 12% or less for the majority of commercial aircraft flight conditions and in so doing is able to minimize weight, size, cost, and operational performance affect on the aircraft 12, while maximizing reliability. This is explained in further detail below.

[0023] The inerting system 10 may be primarily located within an air conditioning pack bay, in adjacent wing fairing areas, or in other suitable areas of the aircraft 12.

[0024] Although, a single inerted fuel tank 16 is shown, the aircraft 12 may have any number of fuel tanks, including center and wing fuel tanks. The fuel tanks may be of various size and shape and be located in various locations on the aircraft 12. The fuel tanks 16 may be adjacent to an environmental control system (not shown) for controlling parameters, such as humidity, cabin air pressure, and rate of change of cabin air pressure.

[0025] The control circuit 14 includes a main controller 40 that adjusts flow of the bleed air through one or more air separation modules (ASMs) 46 to the fuel tanks 16, by the control circuits 15, depending upon phase of flight. In receiving air at a rate sufficient to maintain the inert level of the tank below 12% for most flight conditions, the use of storage tanks to store inerting gas is eliminated, unlike

that of prior art systems. The inerting gas may be in the form of nitrogen-enriched air (NEA) or in some other form known in the art.

[0026] Vents 24 are provided for limiting pressure within the fuel tanks 16. Although a dual vent is shown, any number of vents may be used, including climb vents and dive vents. To prevent leakage of inerting gas and to maintain a consistent oxygen level in the fuel tanks 16, a check valve 25, or equivalent device, is installed in one of the vents 24. The check valve 25 is used to prevent cross-flow and maintain proper oxygen levels in the tanks 16 by preventing leakage of inerting gas.

[0027] The controller 40 modulates the cooling airflow and/or bleed air flow to maintain ASM temperature at an optimum performance level. The controller 40 may modulate inerting gas flow during both flight and ground conditions. The controller 40 may also deactivate portions or all of the system 10 during over temperature or inappropriate operation conditions, which is further described below.

[0028] The controller 40 may be microprocessor based such as a computer having a central processing unit, memory (RAM and/or ROM), and associated input and output buses. The

controller 40 may be an application-specific integrated circuit or may be formed of other logic devices known in the art. The controller 40 may be a portion of a central vehicle main control unit, an interactive vehicle dynamics module, or may be a stand-alone controller as shown. The controller may have external inputs 41.

[0029] The controller 40 also may provide a function status of the system 10 using an external or flight deck status indicator 84. The indicator 84 may include LED(s), light(s), an alphanumeric display system, status message(s) to other aircraft systems, or other indicator known in the art. The indicator 84 may supply system status signals, signals indicating that a component or system is operating inappropriately, or other signals providing inerting system relevant information.

[0030] The ASMs 46 may be of various sizes and styles and have various weights. The present invention minimizes size and weight of the ASM(s) 46 by maintaining oxygen content within the fuel tanks 16 to be approximately equal to or less than 12% for the majority of commercial flight conditions, as opposed to prior art systems that maintain oxygen content levels at 9% or less. By maintaining the oxygen content below a higher percentage the amount of in-

erting gas utilized by the system 10 is decreased, thereby decreasing size and weight of the system 10. Although a single air separation module is shown additional air separation modules may be utilized.

[0031] When one or multiple ASMs are utilized they may be enclosed in a shroud, such as shroud 51. The heat exchanger ram air is heated by the incoming feed or bleed air and the heated ram air exhaust can be ducted into the shroud 51, as designated by arrow 48. Oxygen-enriched air (OEA) can be directed into the shroud 51 mixing with the ram air exhaust. The combined oxygen-enriched air and ram air exhaust is vented overboard, as represented by arrow 49. The ram air exhaust heats the ASMs, thereby, minimizing bleed air/NEA cooling and associated potential condensation of hydrocarbon vapors into liquid form, which reduce ASM performance. OEA designated ducts are not required and the OEA is diluted with ram exhaust air to minimize any hazard associated with the OEA. The heating of the ASMs, such as during climb and cruise modes of operation, increases ASM performance during descent of the aircraft 12.

[0032] The separation circuit 19 receives bleed air 17 from the engines 18 via a bleed valve 50, which is used to control

the supply of pressurized air to an ozone converter 54 or to the heat exchanger 56, when an ozone converter is not utilized. The heat exchanger 56 receives pressurized air from the ozone converter 54 and cools air from a ram air system 60. Air received from the ram air system 60 is controlled via a ram air valve 62. Air flows then through a filter 58 to the ASM(s) 46.

[0033] The ram air system 60 may be a portion of an on-board air-conditioning ram air system, a dedicated ram air system, or some other ram air system known in the art. The ram air system 60 may include a ram air scoop (not shown).

[0034] The ASM(s) 46 separate the pressurized air into inerting gas and oxygen-enriched air. The inerting gas is passed through a main check valve 64 to prevent reverse flow of the fuel from entering the ASM(s) 46. Upon exiting the main check valve 64 the inerting gas is passed to the fuel tanks 16.

[0035] The volume of inerting gas, is controlled via a flow rate control valves 70 and flow orifices 78 and 80. The inerting gas upon passing through the flow control orifices 78 and 80 pass through the check valve(s) 28 and then the float valve(s) 76 before being released into the fuel tanks 16.

Although two orifices are shown, single, multiple, or continuously variable flow orifices may be used.

[0036] One or more witness drain and test port(s) 86 is coupled to the system 10, such as to verify the function of check valve 28, and to allow for functional checks on the ground. Of course, other test ports and check devices may also be incorporated within the system 10.

[0037] Referring now also to Figure 2, a logic flow diagram illustrating a method of supplying inerting gas to the fuel tanks 16 in accordance with an embodiment of the present invention is shown. The following method is described with respect to the controller 40 maintaining oxygen content within the fuel tanks 16 to be at or less than approximately 12% during both ground and flight operating conditions. The method also maintains inert levels before and after landing the aircraft 12 such that the system 10 may be disabled some or all of the time when the aircraft 12 is parked. The method may be easily modified to attain other oxygen content levels.

[0038] In step 100, the bleed air valve 50 receives the bleed air from the engines 18 or from other pressurized air sources. The controller 40 controls flow of the bleed air by the position of the bleed air valve 50. In step 102, the

ozone converter 54 converts ozone to oxygen. The ozone converter 54 converts ozone (O_3) to oxygen (O_2), to improve life and reliability of the ASM(s) 46.

[0039] In step 104, the pressurized air is cooled within the heat exchanger 56 by thermal energy transfer to the ram air. In step 104A, a temperature sensor 83 generates a temperature signal. The temperature sensor 83 is coupled to the controller 40 and to an air flow line, such as line 85, and generates the temperature signal that is indicative of the temperature of the air downstream of the heat exchanger 56. In step 104B, the controller 40 in response to the temperature signal adjusts ram airflow and/or bleed air flow to control temperature at the ASM inlet 47. When the ram air cooling system 60 is saturated at full available cooling or when inappropriate operating conditions exist that can limit ram air cooling, the controller 40 shuts down the system 10 to protect the ASM(s) 46 from unacceptably high temperatures.

[0040] In step 106, the filter 58 filters the cooled pressurized air. The filter 58 removes particles, water vapor, hydrocarbon gases and other contaminates from the high-pressured air before entrance to the ASMs 46.

[0041] In step 108, the ASMs 46 separate the cooled bleed air,

into inerting or nitrogen-enriched air and oxygen-enriched air. The oxygen-enriched air is piped overboard and released out a cooling and oxygen exhaust port 66. Ram air is also exhausted from the heat exchanger 56 out the exhaust port 66 either directly or via the shroud 51, as shown. The inerting gas is permitted to pass to the main check valve 64. When multiple ASMs are utilized, this separation may be performed in parallel via the control valves 70.

[0042] In step 109, the inert gas flow rate is modulated. The controller 40 may regulate the inert gas flow to be lower during climb and/or cruise and higher during descent of the aircraft 12. In step 110, the main check valve 64, the fuel tank check valves 28, and the float valves 76 prevent reverse flow of the inerting gas, thus preventing fuel from flowing back to the ASM(s) 46. In step 112, the main check valve(s) 64 allows the inerting gas to pass from the ASM(s) 46 to the fuel tanks 16.

[0043] In step 114, the check valve 25 controls the flow of vent air within the fuel tanks 16. In step 116, the inerting gas is mixed with the tank ullage. The inerting gas is routed in the tanks 16 through an ejector 82, which utilizes the inerting gas flow to induce addition flow in the tanks 16, to

mix the inerting gas with the tank ullage to minimize oxygen content variations in the tanks 16.

[0044] The above-described steps are meant to be an illustrative example; the steps may be performed synchronously, sequentially, simultaneously, or in a different order depending upon the application.

[0045] The present invention provides a system that has a compact, lightweight, reliable design that is practical to retrofit within an aircraft, or incorporate in initial production. The present invention minimizes size, weight, and system complexity by minimizing component redundancy therein while maintaining inert states within otherwise high flammability fuel tanks of an aircraft. The present invention has significantly reduced maintenance relative to its military predecessors.

[0046] The above-described apparatus and method, to one skilled in the art, is capable of being adapted for various applications and systems known in the art. The above-described invention can also be varied without deviating from the true scope of the invention.